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Influence of the Number of Microthreads on Marginal Bone Loss: A Five-Year Retrospective Clinical Study in Humans

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Featured Application: The design of the crestal module containing 3 to 9 microthreads and with an extension between 1 to 3 mm does not influence the bone level at 5 years of follow-up.

Abstract: The purpose of the present study was to evaluate the clinical and radiographic outcomes of the number of microthreads on marginal bone over 5 years. Thirty-two implants were placed in 32 patients with partially edentulous maxillae or mandibles. Two implants with the same characteristics were placed: the first one had a 1 mm crest module and 3 microthreads (Q); and the second one had a 3 mm crest module and nine microthreads (S). The prosthesis was inserted 3 months after implant placement. Clinical and radiographic examinations were performed at the one-week, one-month, and three-month follow-up visits and then every six months until a five-year follow-up period was completed. After 5 years of follow-up, five patients withdrew from the study. Complete data were available for 27 implants, with a 100% implant survival rate. No cases of peri-implantitis were diagnosed. The average bone loss was 0.65 mm (C.I. 0.21–1.09) for Q implants and 0.86 mm (C.I. 0.39–1.33) for S implants, with no statistically significant difference. The bone level does not vary between implants with three and nine microthreads or with a 1 mm and 3 mm crest module. No differences in clinical parameters were found.

Keywords: dental implant; alveolar bone; microthreads; peri-implant bone loss; implant designs

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1. Introduction

Generally, a 1.5 mm of crestal bone loss around dental implants during the first year, followed by a 0.2 mm of loss in subsequent years, has been considered acceptable [1,2].

More recent studies have advocated that the maintenance of the initially achieved peri-implant bone level (BL) as coronally as possible is crucial for long-term success and good aesthetic results of implant therapy [3].

Many variables are related to marginal bone loss, including surgical trauma, occlusal overload, peri-implantitis, microgap, biologic width, and implant crest module [4–6].

Some of the factors mentioned above are highly influenced by implant-related factors, such as the macrogeometry of the implant, the implant-abutment connection, and the position of the coronal rim in relation to the crestal bone [7–11]. However, whether an implant is a one-stage or two-stage implant does not seem to be of great significance [3,12].

The manner in which load stress is transferred to bone surrounding an implant is decisive when considering bone maintenance [13]. For this reason, several modifications have been introduced in the macro- and microgeometry of this type of fixture to enhance the rate and extent of osseointegration [14,15], promote the preservation of peri-implant tissues [16,17], and shorten the treatment time [7].

The crest module is the coronal part of the implant that is closely related to the bone cortex and plays an important role in stress distribution. The crest module is designed with a smooth or rough morphology.

Smooth modules are designed to be inserted in a supra-crestal manner to avoid the accumulation of dental plaque, and their infracrestal insertion favours bone loss [18–21]. In contrast, modules with a rough surface have been shown to better distribute load stress on the bone cortex and are designed for infracortical use [22], although they may increase the difficulty of hygienic maintenance [23].

Dental implant microthreads are an innovative solution to the problem of dental implants failing due to weak attachment. The microthreads are designed to be flexible and promote bone growth, creating an even stronger bond between the implant and the surrounding jawbone. This technology is becoming more popular among dental professionals as it has been proven to be an effective way to increase the success rate of dental implants.

However, considering the onset of peri-implantitis, no difference has been found between implant collars with a rough or smooth surface [24,25].

Despite the literature on this topic, there remain gaps in the current research. For example, most of the research in this field has focused on finite element studies with limited research on the clinical impact in humans. It has long been proven that the presence of a rough surface or the presence of microthreads improves the distribution of mechanical stress, especially shear forces. However, we do not know the minimum number of spires required to achieve this effect, or the maximum number of spires above which no improvement would be noticeable. In addition, potential risks remain to be determined, especially during long-term follow-up periods. Therefore, more research is needed to determine the role of the number of microthreads and the potential risks of increased incidence of peri-implant disease and bone loss in humans.

The number and distribution of microthreads in the crest module is a factor that has not been extensively studied. The purpose of the present study was to determine whether the presence of three microthreads and a 1 mm long neck versus the presence of nine microthreads and a 3 mm long neck makes a difference in the maintenance of bone over 5 years around implants subjected to the same surface treatment.

The null hypothesis of the study is that there is no significant difference between the number of microthreads and bone level in implants followed-up for 5 years.

2. Materials and Methods

2.1. Material

2.1.1. Patients

A total of 32 patients who needed tooth replacement for different reasons and were treated at the Dental School, University of Murcia, from 1 January 2016 to 15 May 2016 were enrolled. They were patients who did not require guided tissue regeneration or bone grafting techniques.

2.1.2. Implants

The implants were from the same manufacturer (Ticare®, Mozo Grau, Valladolid, Spain) and were subjected to the same resorbable blasting media (RBM) surface treatment but had a different number of threads in the crest module (Figure 1).

Implants were considered as the unit of measurement and only one implant per patient was studied, being this the first implant inserted in the case of needing several implants.

2.1.3. Clinical Evaluation

The plaque index, bleeding index, probing pocket depth and presence of recession were evaluated in each clinical evaluation. Follow-up evaluations were performed one week, one month, and three months after the prosthesis was placed and then every six months until the five-year period was completed.

At the time of abutment placement (2 months after insertion) the implants were considered successful when they met the Albrektsson success criteria. In summary: an absence of mobility, an absence of pain, an absence of radiographic radiolucency, and an absence of invasion of anatomical structures.

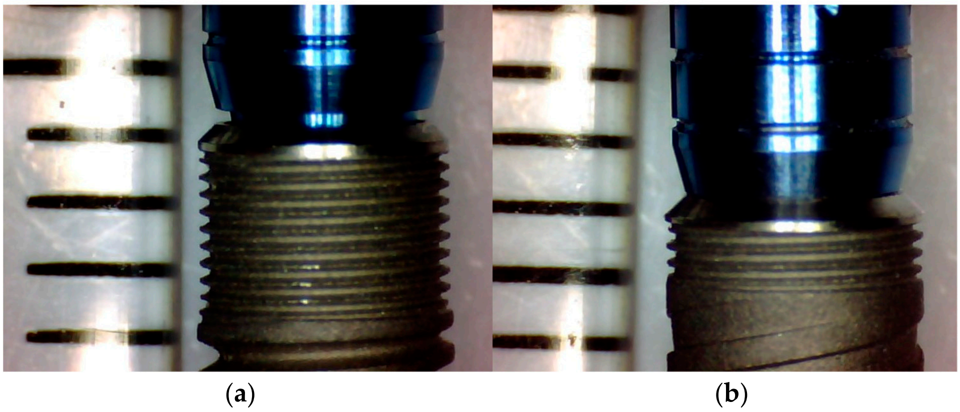

Figure 1. Left: (a) Ticare Inhex Standard implant with nine microthreads and a length of 3 mm; Right: (b) Ticare Inhex Quattro implant with three microthreads and a length of 1 mm.

2.1.4. Radiographic Study

All implants were radiographed at the time of prosthesis placement, which was considered baseline (Kodak CS 2100, Carestream, Rochester, NY, USA). Subsequently, the result was compared with that at the five-year follow-up by means of a second radiograph.

2.1.5. Radiographic Technique

X-rays were obtained using the perpendicular technique with a bite block.

2.1.6. Evaluation of Radiographs

Radiographs were analysed after image calibration using the length and diameter of the implant.

2.1.7. Measurement Program

Open source, public domain ImageJ software was used (the U.S. National Institutes of Health, Bethesda, MD, USA) [26].

2.1.8. Examiner Calibration

Ten duplicate blinded measurements were made at a three-week time interval, and their agreement was analysed using the interclass correlation coefficient test.

2.1.9. Inclusion Criteria

Patients who signed the informed consent form and who accepted the use of their data after anonymization.

Patients were over 18 years of age.
Patients classified as ASA stage 1 or 2.
Patients requesting outpatient treatment.
Patients with integrated dental implants.
Patients who met the Albrektsson success criteria.
Patients undergoing regular maintenance.
Patients with a plaque index ≤ 1 (Löe and Silness).
Patients with a gingival index < 1 (Silness and Löe).

2.1.10. Exclusion Criteria

Undefined images.
Patients who were erratic in their appointments.
Patients who smoked.

Patients with a history of systemic diseases potentially contributing to the risk of implant loss.

Patients who were pregnant at any time during the evaluation period, which would preclude the use of intraoral radiography.

2.2. Method

The patients included in the study were those who received Inhex implants with similar surface characteristics but with a different number of threads in the neck. The implants were inserted following the manufacturer's drilling protocol (Ticare®, Mozo Grau, Valladolid, Spain). The drilling speed was 800 rpm, and the torque was 20 N.

All patients provided consent for the use of the data obtained during their treatment. The study was performed following the recommendations of the Declaration of Helsinki [27]. The Ethics Committee of the University of Murcia approved the study protocol (ID: 2076/2018).

Patients enrolled in the study underwent digital radiovisiography at the time of prosthesis placement. Patients were enrolled in a randomised sequential pattern. A representative sample of 32 implants was chosen, 16 of them corresponding to the Ticare Inhex Standard® design (S) and 16 to the Ticare Inhex Quattro® design (Q) (Mozo Grau, Valladolid, Spain). The implants were inserted between 1 January 2016 and 15 May 2016. Once the study period had elapsed, a second radiographic evaluation was performed (5 years after loading).

The evaluation was performed using ImageJ software (the U.S. National Institutes of Health, Bethesda, MD, USA) once the images had been calibrated. The B.L. was measured from the neck of the implant to the first contact between the bone and the implant, both mesially and distally. All measurements were taken in mm. The mean of both measurements was taken as the B.L. measurement of the implant. These measurements were taken both at the time of prosthesis placement and after 5 years for both types of implants (Figure 2).

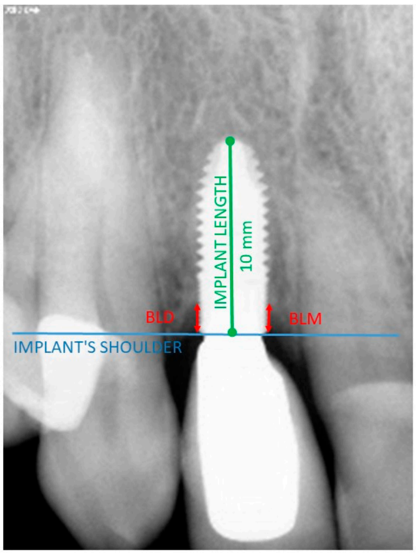

Figure 2. Measurements taken to determine the bone level (BL). Calibration of the program based on implant length and diameter. BLM = mesial bone level, BLD = distal bone level. The B.L. for a given implant and time was calculated as the mean of both measurements (BLM + BLD/2).

Data were analysed using the Shapiro-Wilk test to determine the normality of the distribution.

For statistical analysis, mean values were compared using the Kruskal-Wallis test and Wilcoxon signed-rank test, with $p < 0.05$ considered significant.

An interclass correlation coefficient model, which is a regression model that aims to quantify the degree of joint variation between two quantitative variables, was used to evaluate the reliability of the evaluator. The results represent the internal consistency of the evaluation, i.e., the degree to which the values of the two measurements covary with each other. The correlation coefficient ranges from 0 to 1, where 1 indicates a maximum level of consistency between the two measurements and 0 indicates the minimum level of consistency.

The confidence interval agreement scores were categorised according to the following classification of conventional values for the ICC:

<0.40—Poor.
0.40–0.59—Sufficient.
0.60–0.74—Good.
0.75–1—Excellent.

3. Results

3.1. Evaluator Reliability Analysis

Regarding the calibration of the evaluator, two repeated measurements of 10 radiographs separated by 21 days were established, and the interclass correlation coefficient was calculated.

The results showed excellent agreement between both measurements, with a Cronbach alpha of 0.924 for weighted bone loss (B.L.). The worst result was found for the distal bone loss measurement (B.L.D.), with a Cronbach alpha of 0.838. The value indicating the concordance of the mesial bone loss (M.B.L.) measurements was 0.869. All values indicated excellent concordance.

3.2. Description of the Sample

A total of 32 implants were evaluated over 5 years. The mean age of the patients was 61.72 years (I.Q. 57.99–65.45); 14 implants were inserted in men (43.75%) and 18 in women (56.25%). Of these, 15 implants were inserted in the mandible (46.9%) and 17 in the maxilla (53.1%). Eight were placed from canine to canine (25%), 9 in premolars (28.1%) and 15 in molars (46.9%) (Tables 1 and 2, and Figure 3).

Table 1. Bone level values for the two implants at the time of loading (3 months after insertion and 5 years after insertion). BLM1, mesial bone level at 3 months; BLD1, distal bone level at 3 months; BL1, mid-bone level at 3 months (BLM1 + BLD1/2). S = Standard implant, Q = Quattro implant.

BLM1	Q	Mean		0.5393
		95% confidence interval for mean	Lower limit	0.1239
			Upper limit	0.9547
	S	Mean		0.5283
		95% confidence interval for mean	Lower limit	0.0326
			Upper limit	1.0240
BLD1	Q	Mean		0.4764
		95% confidence interval for mean	Lower limit	0.0727
			Upper limit	0.8801
	S	Mean		0.6175
		95% confidence interval for mean	Lower limit	0.0129
			Upper limit	1.2221
BL1	Q	Mean		0.5079
		95% confidence interval for mean	Lower limit	0.1253
			Upper limit	0.8904
	S	Mean		0.5729
		95% confidence interval for mean	Lower limit	0.0618
			Upper limit	1.0840

Table 2. Bone level values for the two implants at 5 years after loading. BLM2, mesial bone level at 5 years; BLD2, distal bone level at 5 years; BL2, mid-bone level at 5 years (BLM2 + BLD2/2). S = Standard implant, Q = Quattro implant.

BLM2	Q	Mean		0.6871
		95% confidence interval for mean	Lower limit	0.2225
			Upper limit	1.1517
	S	Mean		0.7042
		95% confidence interval for mean	Lower limit	0.1864
			Upper limit	1.2220
BLD2	Q	Mean		0.6229
		95% confidence interval for mean	Lower limit	0.1617
			Upper limit	1.0841
	S	Mean		1.0217
		95% confidence interval for mean	Lower limit	0.5456
			Upper limit	1.4978
BL2	Q	Mean		0.6550
		95% confidence interval for mean	Lower limit	0.2140
			Upper limit	1.0960
	S	Mean		0.8629
		95% confidence interval for mean	Lower limit	0.3922
			Upper limit	1.3336

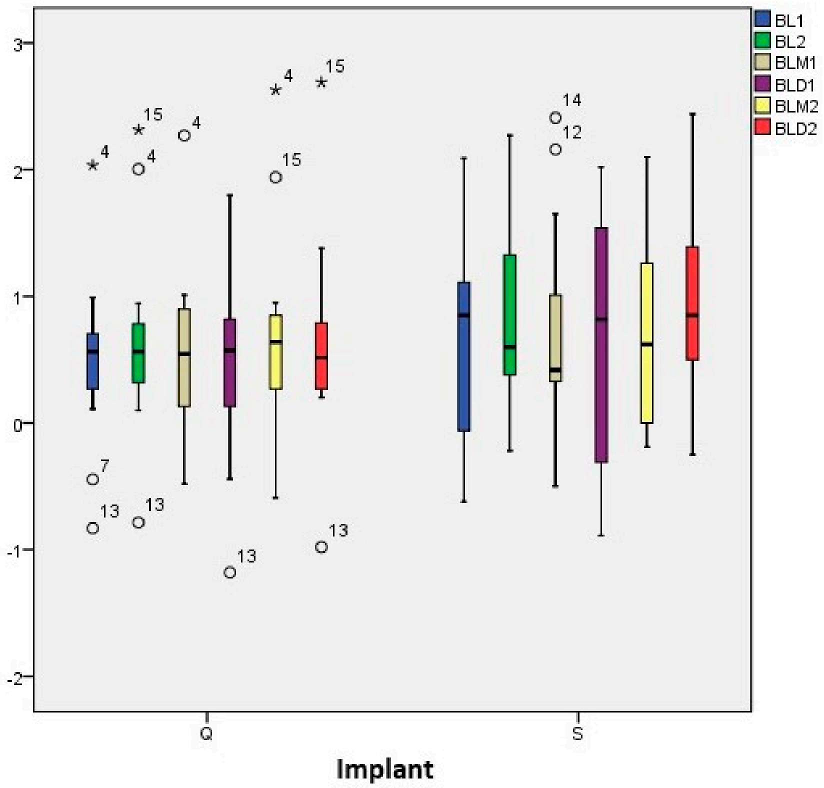

Figure 3. Box plot of bone level measured at 3 months and 5 years, grouped according to implant type. S = Standard implant, Q = Quattro implant. O = Outliers. * = Extreme outliers.

The results for the marginal B.L. are shown in Tables 1 and 2, and Figure 3.

3.3. B.L. Analysis between Groups

3.3.1. Comparison of B.L. between Groups at 3 Months after Loading

Given the sample size, the nonparametric Kruskal-Wallis test was applied and showed no statistically significant difference in BLM1, BLD1, or BL1 between the two implant designs at three months after loading.

As both samples were equal at the time of loading, this result indicates that the B.L. is not influenced by the number of threads at the beginning of the study and that both samples are homogeneous and comparable (Figure 4).

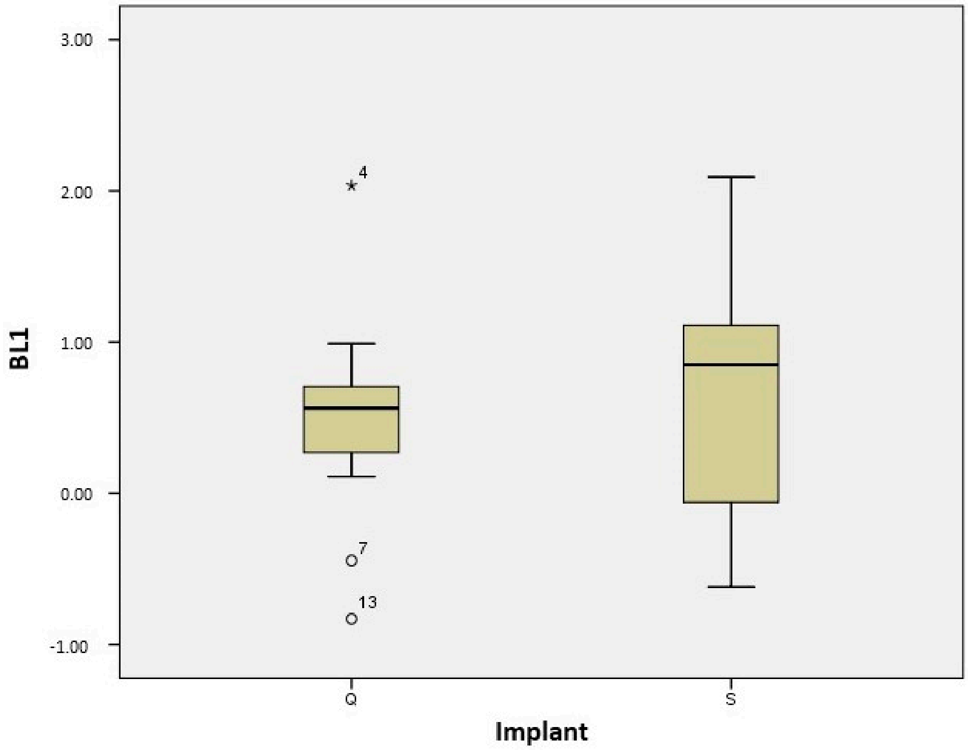

Figure 4. Box plot of the bone level for both implant designs at loading (baseline), with no statistically significant difference between them. S = Standard implant, Q = Quattro implant. O = Outliers. * = Extreme outliers.

3.3.2. Comparison of B.L. between Groups at 5 Years after Loading

We found no statistically significant difference in BLM2, BLD2, or BL2 between the two implant designs at 5 years after loading.

At 5 years after loading, the B.L. was not influenced by the number of threads, which suggests that the same cortical B.L. level can be maintained with both designs.

Therefore, a thread count between three and nine for Ticare Inhex Standard and Quattro implants does not influence the B.L. of bone preservation (Figure 5).

3.3.3. Comparison of Intragroup B.L. over Time (3 Months vs. 5 Years)

We compared the B.L. results for each type of implant between 3 months and 5 years by comparing BLM1 with BLM2, BLD1 with BLD2, and BL1 with BL2. We found no statistically significant difference in any of the variables studied between these two time points.

Therefore, a thread count between three and nine does not influence bone maintenance around Ticare® implants (RBM) over five years.

Notably, six patients were lost to follow-up over 5 years, two due to a change of address and four due to nonattendance at the five-year maintenance appointment.

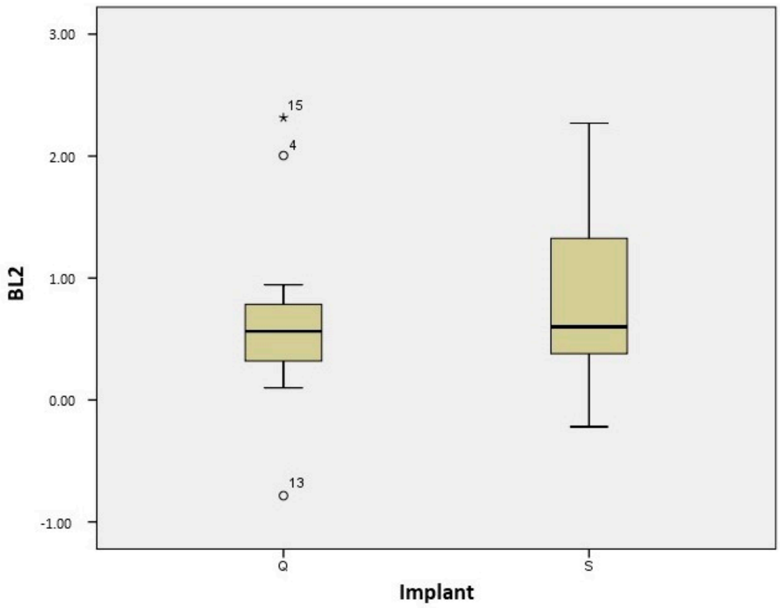

Figure 5. Box plot of bone level for both implant designs at 5 years after loading (deadline), with no statistically significant difference between them. S = Standard implant, Q = Quattro implant. O = Outliers. * = Extreme outliers.

4. Discussion

Research and development in the field of implantology are constantly focusing on combining the principles of cell biology, engineering, biochemistry, molecular biology, and biomaterials [28].

In the 1970s, the accepted paradigm was that dental implants should have as polished a neck as possible to prevent plaque accumulation. For this reason, most implant manufacturers at this time adopted this design. However, finite element studies showed that stress peaks, especially with shear forces, and the stress is concentrated in the crestal bone surrounding the polished collars. Since cortical bone is 65% less resistant to shear forces than to compressive forces, we could say that the loss of bone level that occurred during the first year of function could be attributed to the lack of adequate distribution of mechanical stress between the coronal region of the implant and the surrounding bone [4].

For this purpose, we have carried out the present five-year study comparing the result between three and nine microthreads with an extension between 1 and 3 mm on the surface of the crestal module.

The microthreads are extremely effective in increasing the success rate of dental implants. Studies have shown that implants with microthreads have a greater success rate than traditional implants. This is due to the increased strength of the bond between the implant and the surrounding jawbone.

Clinical findings suggest that the resulting changes, particularly in implant design, have contributed to the success of dental implantation [29]. These new designs help with load transfer to cancellous bone rather than cortical bone; thus, less cortical bone resorption may occur [10].

Our study focused on the crest module and the influence of the number of microthreads on the B.L. The crest module is the neck portion of the implant and plays a critical role in minimizing stress on the neck portion of the dental implant [13].

Microthreads are a feature of dental implant designs that consist small fine threads to help secure the implant after insertion into the implant site. Implant systems with microthreads are designed to provide greater implant stability and longer-term success than traditional implant systems. However, there are a wide variety of designs [30]. For this reason, we used the same implant with different numbers of microthreads to standardise the material, diameter, length, platform, and surface (RBM).

Among the factors of the crest module that have attracted the attention of researchers, the following are worth noting:

- Collar design;
- Presence of microthreads;
- Beginning of microthreads;
- Number and length of microthreads.

4.1. Collar Design

One of the aspects that has had the greatest influence on implant design has been the collar design [31–33]. Thus, the design and characteristics of this part of the implant have become a fundamental aspect of stress distribution [34–36].

The occlusal forces on dental implants are transmitted primarily through the cortical bone, and thus, the intensity and concentration of stress (von Mises stress) are distributed through the crest module in the cortical bone [13,22].

Research findings have indicated that implants with a narrow thread pitch, which increases the implant surface area, provide better stress distribution and stronger primary stability, especially in low-density bone [9,13].

4.2. Presence of Microthreads

Several finite element analysis (FEA) studies have noted the importance of including microthreads to improve the distribution of occlusal loads [37–39]. This effect is increased in the case of fixed prostheses with extensions [40]. Moreover, this effect seems to be due to the dissipation of horizontal and oblique forces and not be as important for axial loads [36]. Several clinical studies have also found a beneficial effect of implants incorporating microthreads on the maintenance of the (B.L.) [41–43]. Furthermore, this beneficial effect has been confirmed by a systematic review study with meta-analysis [44].

However, some authors have questioned the efficacy of microthreads upon finding no difference between their presence or absence [38]. Others consider the presence of microthreads to pose an increased risk of peri-implantitis [23]. However, clinical studies have not confirmed the latter in humans [24,25] or animals [45].

4.3. Beginning of Microthreads

It is worth highlighting an interesting study comparing two implants where the only difference between them was the location of the microthreads. In one of the implants, the microthreads began at the top of the implant neck, and in the other, the microthreads began 0.5 mm lower. According to this clinical study, after one year, less peri-implant bone loss was observed around implants with microthreads placed at the top of the implant [23]. These findings coincide with those of FEA studies [46].

4.4. Number and Length of Microthreads

Another interesting aspect is the length of the crest module and consequently the number of microthreads. The number of microthreads varies depending on the size of the implant and typically ranges between 3 and 15. Similarly, the length of a dental implant crest module can vary depending on the size and type of implant being used. Generally, the length of a crest module ranges from 0.5 to 4 mm.

We have not found any clinical studies with which to compare our results. Only one study using FEA has addressed this topic. According to this work, a length of 3 mm is recommended, especially if the implant is to receive oblique or horizontal loads [46].

However, in our five-year clinical study, we found no such differences between implants with a length of 1 mm and three microthreads or a length of 3 mm and nine microthreads. We observed that the Ticare Inhex Quattro (three microthreads, 1 mm in length) and Ticare Inhex Standard (nine microthreads, 3 mm in length) implants did not show a statistically significant difference in the marginal (B.L.) after 5 years of function. There were also no statistically significant differences in the clinical variables (plaque index, bleeding index, probing depth, and presence of recession).

As mentioned above, we have not found similar clinical studies with which to compare our results. The clinical studies we found have a mean follow-up ranging from 3 to 12 months [6,23,41–43,47]; one study had a follow-up period reaching 3 years and up [48], and two studies had a follow-up period of 5 years [49,50].

A study by Mei et al. [50] was performed with delayed implantation and showed good performance for implants with platform switching, microthreads, and a rough surface (SLA). Their results are consistent with ours; however, this study lacked a control group.

The second study we found with results after 5 years reported no difference between the presence or absence of microthreads [49]. However, this study evaluated insertion after immediate implantation, and as has been demonstrated, this technique does not prevent bone resorption, regardless of implant design. It has been mentioned that immediate implant installation is conducive to predictable osseointegration and high survival rates but fails to prevent bone remodelling and dimensional reduction of the alveolar ridge [51].

Most of the relevant studies have been performed using FEA models, which should be assessed more qualitatively than quantitatively due to the need for a precise fit.

Among the FEA studies most similar to our study, we found one that studied the presence of microthreads over a length of 1, 2, or 3 mm [46]. These researchers concluded that a length of 3 mm yielded the best results, especially for implants subjected to nonaxial loads.

Another study investigated different histomorphometric bone changes around non-submerged implants with different machined collar lengths (1.6 vs. 0.4 mm) in a dog model. The researchers concluded that crestal B.L. changes were reduced when implant necks with a rough surface were used [31].

On the other hand, reviews, systematic reviews, and meta-analyses have yielded controversial results due to the heterogeneity of the included studies [30,35,44].

The exact effect of subcrestal insertion on dental implant stability is still under investigation. However, research has shown that subcrestal insertion may help improve implant stability and reduce the risk of failure. Studies have demonstrated that inserting a dental implant slightly subcrestal can help increase primary stability, reduce micro-movement, and improve implant osseointegration. Additionally, subcrestal insertion may help reduce crestal bone resorption and decrease the risk of implant failure.

Currently, many of the accepted paradigms have been questioned. In order to guarantee an adequate clinical outcome, we no longer look for the longest and widest implants possible, since short but well-designed implants are capable of obtaining an adequate clinical outcome [52].

The study on the effect of microthreads on bone loss yielded results supporting the hypothesis that microthreads can reduce bone loss with no difference found between three or nine microthreads or between 1 or 3 mm.

The conclusions should be reinforced highlighting the strengths and weaknesses of the study about dental implant microthreads. This study about dental implant microthreads was a clinical investigation into the effects of the number of microthreads on bone level. The results showed that bone level was stable regardless of the number of microthreads studied. Specifically, the presence of microthreads demonstrated its ability to maintain bone level during a five-year follow-up without finding differences between three or nine microthreads. At the same time, the study had some weaknesses. For example, the study did not consider the effects of microthreads geometry, and neither the surface roughness of the implant. Hence, different geometries or roughness may have different clinical behaviour. Additionally, the study did not assess the effects of microthreads on the long-term success of dental implants (more than 5 years).

Another limitation that we should consider is the platform-switched and the level of insertion of an implant. As has been demonstrated, both variables can be of paramount importance in the maintenance of the bone level [53]. Therefore, further research is needed to fully understand the effects of microthreads geometry on implant longevity and surface roughness.

5. Conclusions

Within the limits of the present study, it is concluded that the (B.L.) does not vary between implants with three and nine microthreads or with a length between 1 mm and 3 mm.

No differences in probing depth, plaque, or gingival indices were found, and no cases of peri-implantitis were detected clinically or radiographically.

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Informed Consent Statement: Not applicable.

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